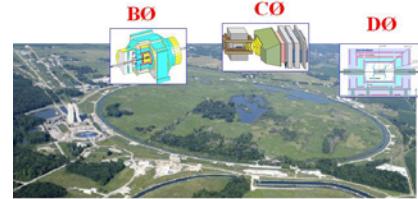




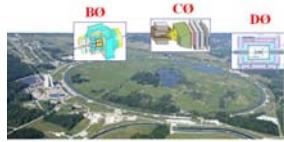
btev



# QCD Physics with BTeV



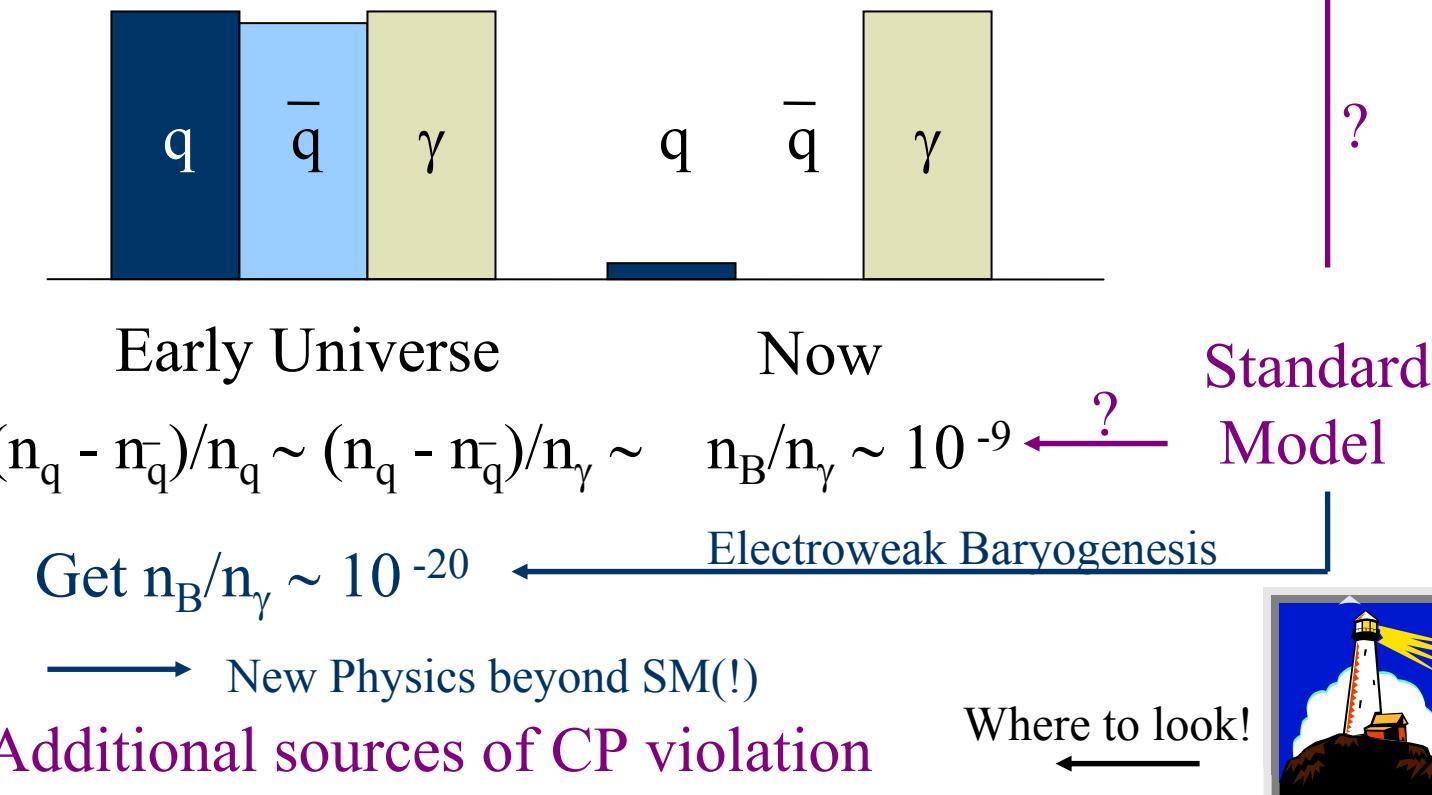
- The main physics motivation for BTeV
  - CP Violation using b & c decays
  - Physics Beyond the Standard Model
- Detector description
- Expectations for QCD studies at BTeV

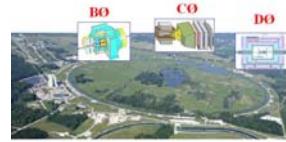


# CP Violation: A Fertile Frontier

How did we become a matter (dominated) universe?

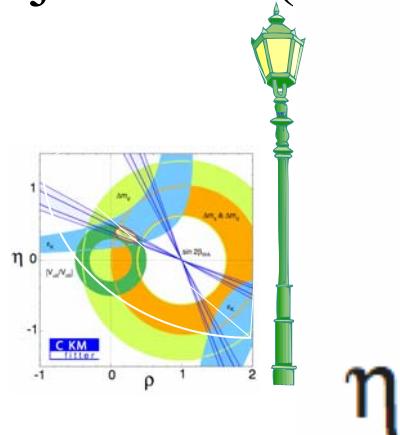
Andrei Sakharov's conditions (1967):



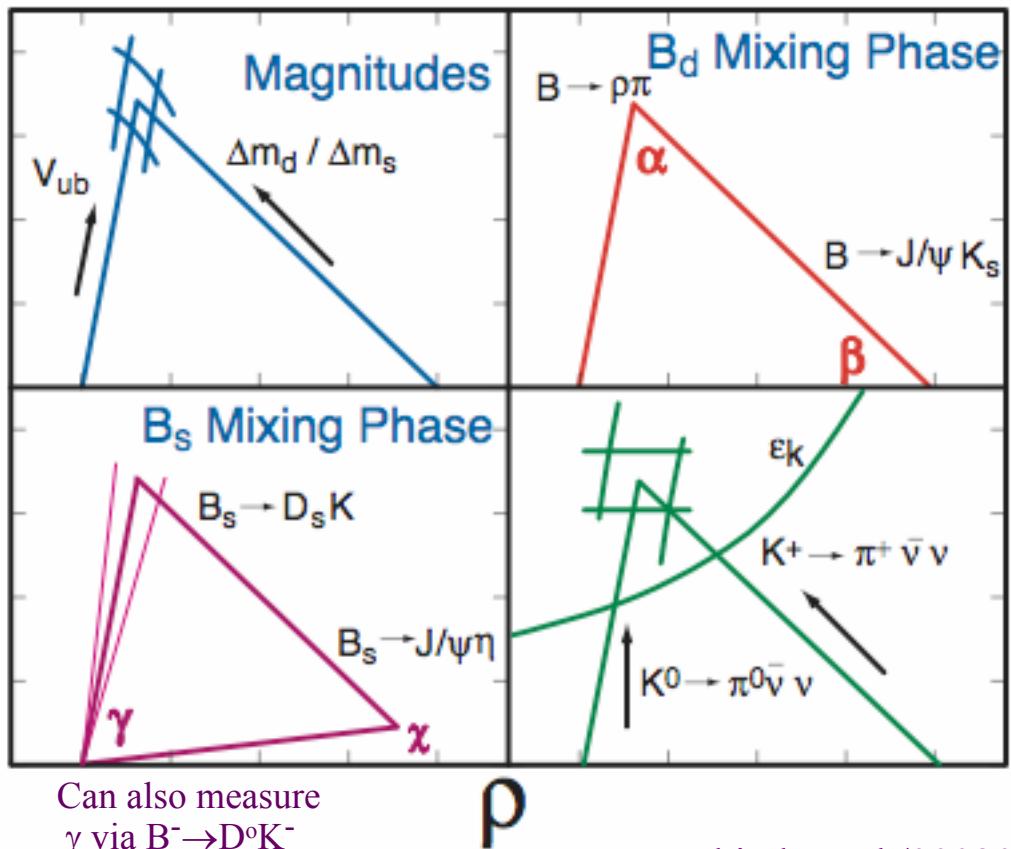


# Measurements of the CKM Matrix

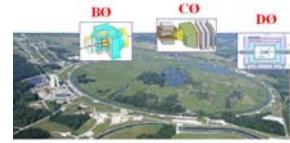
Don't just look (measure) under one lamp post!



- Compare to the comprehensive tests of EW: repeat for quark flavour physics!



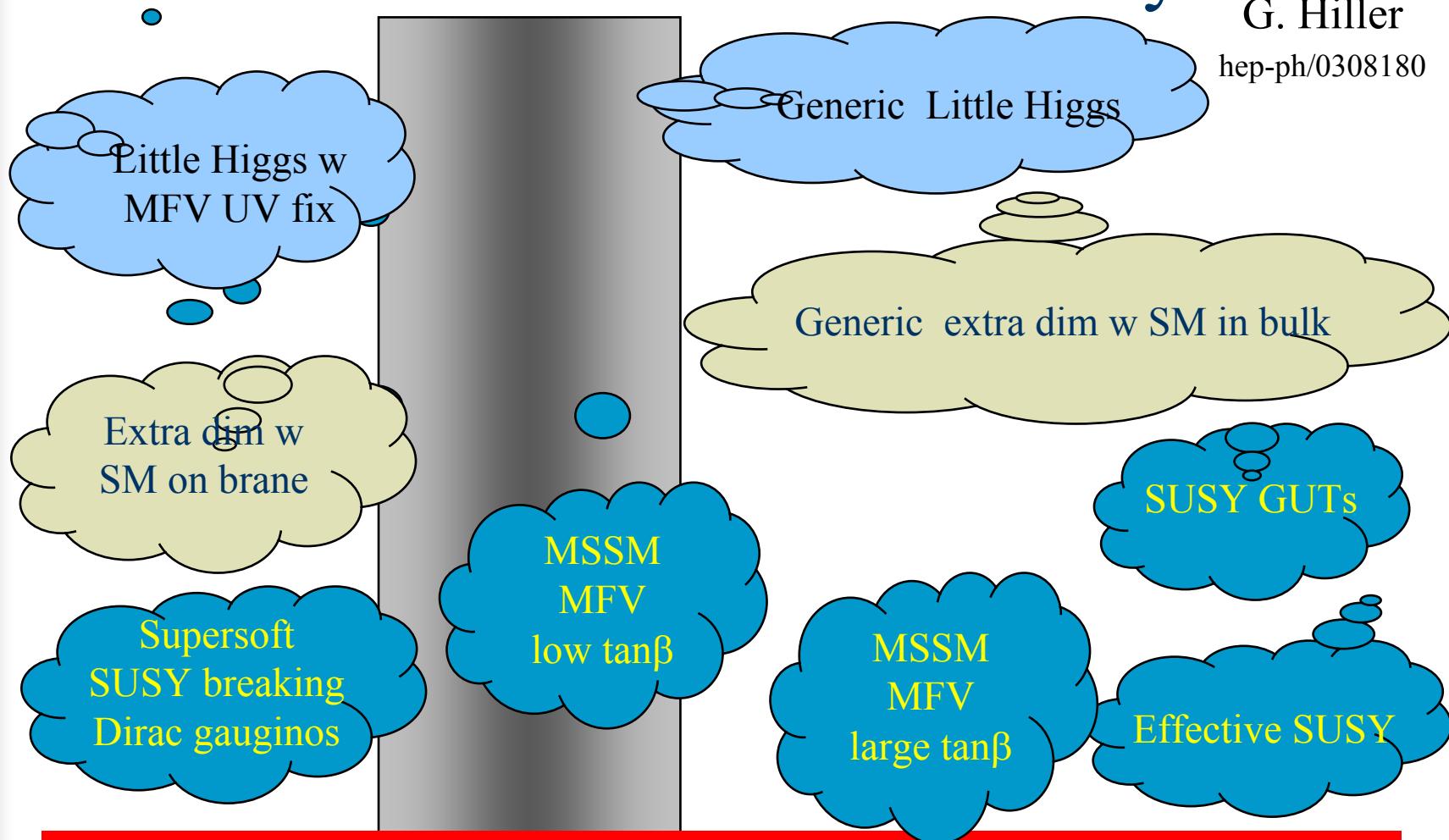
From Peskin hep-ph/0002041



# Flavour Violation in Models which address the Hierarchy

G. Hiller

hep-ph/0308180



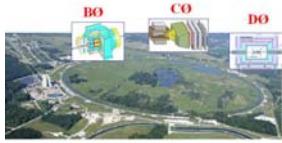
SM-like  $B$  physics

New Physics in  $B$  data

Harry W. K. Cheung

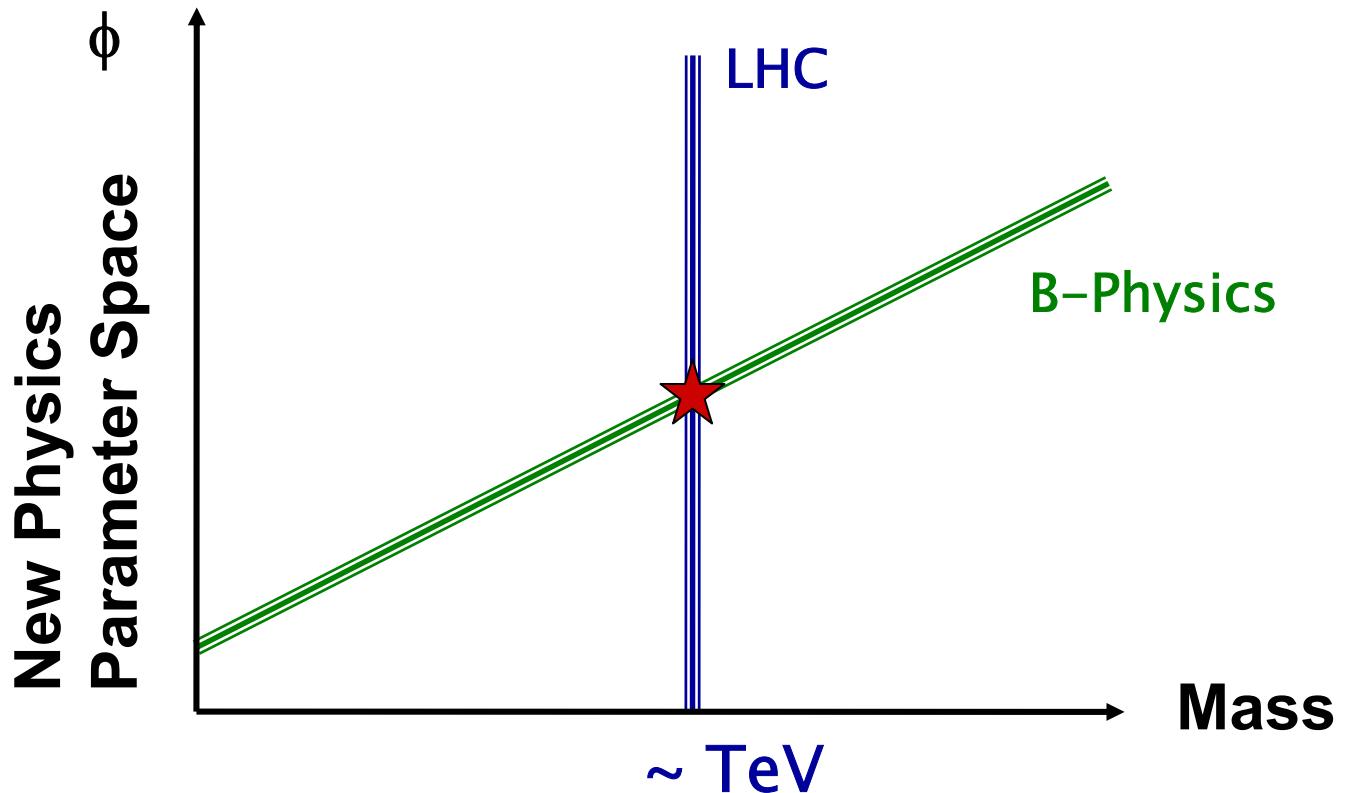
Workshop on the Future of QCD at the  
Tevatron, May 22, 2004

vevtev

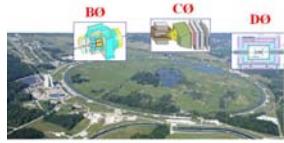


# Physics Beyond the SM: LHC?

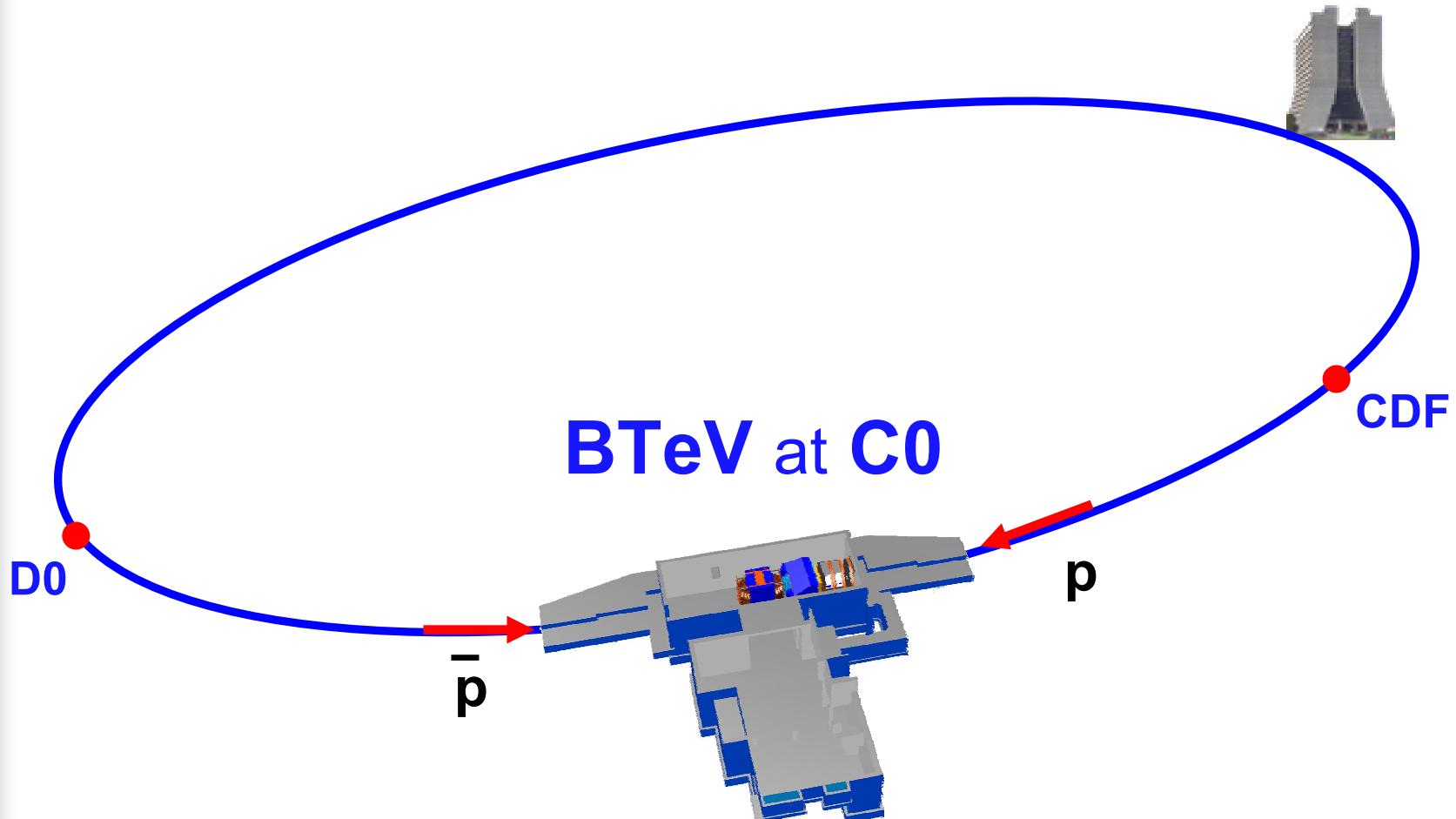
Pictorial Example from Hewett (WIN03):

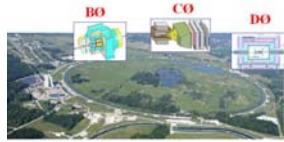


Complementary knowledge from LHC and B Decays!



# BTeV at the Fermilab Tevatron





# BTeV Collaboration

Origins: ■ Fnal FT   ■ CLEO   ■ Hera/HeraB

**Belarussian State:** D.Drobychev,  
A.Lobko, A.Lopatrik, R.Zouversky

**UC Davis:** P.Yager

**Univ. of Colorado:**

J.Cumalat, P.Rankin, K.Stenson

**Fermilab:** J.Appel, E.Barsotti,  
C.N.Brown, J.Butler, H.Cheung,  
D.Christian, S.Cihangir, M.Fishler,  
I.Gaines, P.Garbincius, L.Garren,  
E.Gottschalk, A.Hahn, G.Jackson,  
P.A.Kasper, P.H.Kasper, R.Kutschke,  
S.Kwan, P.Lebrun, P.McBride,  
J.Slaughter, M.Votava, M.Wang, J.Yarba

**Univ. of Florida:** P.Avery

**University of Houston:** A.Daniel,  
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V.Rodriguez, S.Subramania, G.Xu

**Illinois Institute of Technology:**  
R.A.Burnstein, D.Kaplan, L.M.Lederman,  
H.A.Rubin, C.White

**Univ. of Illinois:** M.Haney, D.Kim,  
M.Selen, V.Simaitis, J.Wiss

Harry W. K. Cheung

**INFN - Frascati:**

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M.Giardoni, A.La Monaca,  
E.Pace, M.Pallotta, A.Paoletti

**INFN - Milano:** G.Alimonti,  
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D.Lunesu, S.Magni, D.Menasce,  
L.Moroni, D.Pedrini, S.Sala,  
L.Uplegger

**INFN - Pavia:** G.Boca,  
G.Cossali, G.Liguori, F.Manfredi,  
M.Manghisoni, M.Marengo, L.Ratti,  
V.Re, M.Santini, V.Speciale,  
P.Torre, G.Traversi

**IHEP Protvino, Russia:**

A.Derevchikov, Y.Goncharenko,  
V.Khodyrev, V.Kravtsov,  
A.Meschanin, V.Mochalov,  
D.Morozov, L.Nogach, P.Semenov,  
K.Shestermanov, L.Soloviev,  
A.Uzunian, A.N.Vasiliev

**Univ. of Insubria in Como:**

P.Ratcliffe, M.Rovere

**University of Iowa:**

C.Newsom, & R.Brauner

Workshop on the Future of QCD at the  
Tevatron, May 22, 2004

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R.Poling, A.Smith

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B.P.Zhang, Z.Xi Zhang, J.W.Zhao

**New Mexico State Univ.:**

V.Papavassiliou

**Northwestern University:**

J.Rosen

**Ohio State University:**

K.Honscheid, & H.Kagan

**Univ. of Pennsylvania:**

W.Selove

**Univ. of Puerto Rico:**

A.Lopez, H.Mendez, J.E.Ramirez  
W.Xiong

**Univ. of Science & Tech. of  
China:** G.Datao, L.Hao, Ge Jin,

T.Yang, & X.Q.Yu

**Shandong Univ. (China):**

C.F.Feng, Yu Fu, Mao He, J.Y.Li,  
L.Xue, N.Zhang, & X.Y.Zhang

**Southern Methodist Univ.:**

T.Cowan, M.Hosack

**Syracuse University:**

M.Artuso, S.Blusk, J.Butt,  
C.Boulahouache,  
O.Dorjkhaidav, J.Haynes,  
N.Menaa,

R.Mountain, M.Muramatsu,  
R.Nandakumar, L.Redjimi, R.Sia,  
T.Skwarnicki, S.Stone, J.C.Wang,  
K.Zhang

**Univ. of Tennessee:**

T.Handler, R.Mitchell

**Vanderbilt University:**

W.Johns, P.Sheldon,  
E.Vaandering, M.Webster

**Univ. of Virginia:**

M.Arenton, S.Conetti, B.Cox,  
A.Ledovskoy, H.Powell,  
M.Ronquest, D.Smith,  
B.Stephens, Z.Zhe

**Wayne State University:**

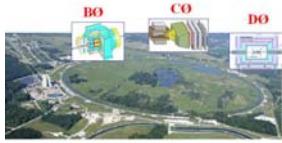
G.Bonvicini, D.Cinabro,  
A.Shreiner

**University of Wisconsin:**

M.Sheaff

**York University:** S.Menary

**bTeV**

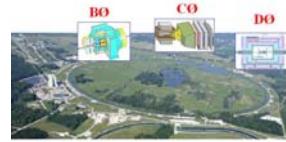


# Why do b and c Physics at Tevatron?

- Large samples of b quarks
  - Get  $\sim 4 \times 10^{11}$  b hadrons per  $10^7$ s at  $L = 2 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$
  - $e^+e^- \Upsilon(4S)$  get  $2 \times 10^8$  B hadrons per  $10^7$ s at  $10^{34} \text{ cm}^{-2}\text{s}^{-1}$
- $B_s$ ,  $\Lambda_b$  and other b-flavored hadrons are accessible for study at the Tevatron
- Charm rates are  $\sim 10\times$  larger than b rates

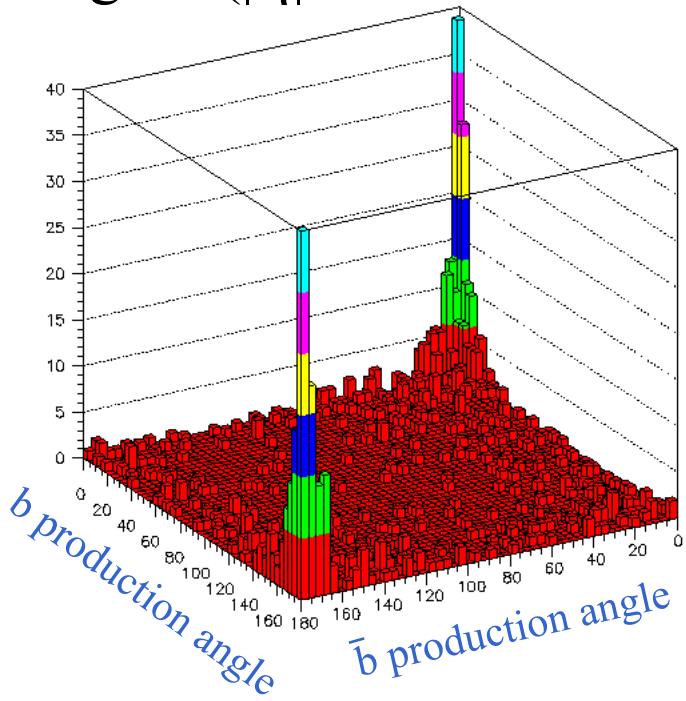
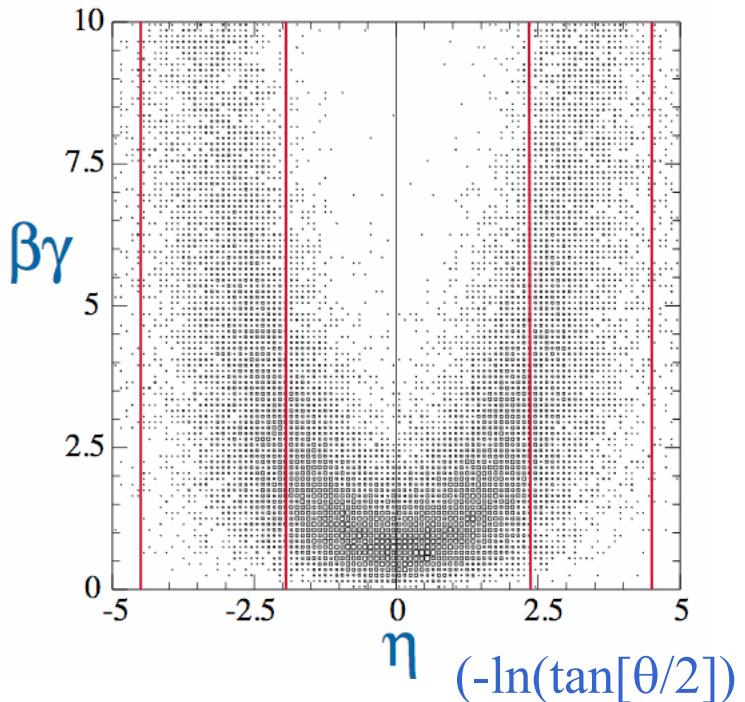
Some assumed parameters for the Tevatron for simulations:

- CMS energy = 2 TeV and  $L = 2 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$
- Time/crossing = 396 ns
- Interaction region  $\sigma_z = 30\text{cm}$  and  $\sigma_{x,y} = 50\mu\text{m}$
- $\bar{b}b$  cross section = 100  $\mu\text{b}$



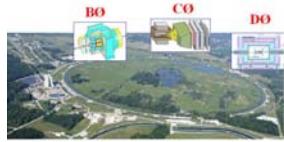
# Why look in the Forward Region?

BTeV detects in the forward region ( $|\eta|$  from 1.9 to 4.5)

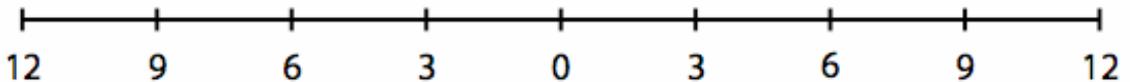


- Better decay length separation
- Less multiple scattering

- More  $B\bar{B}$  in the Detector
- Better away side tagging

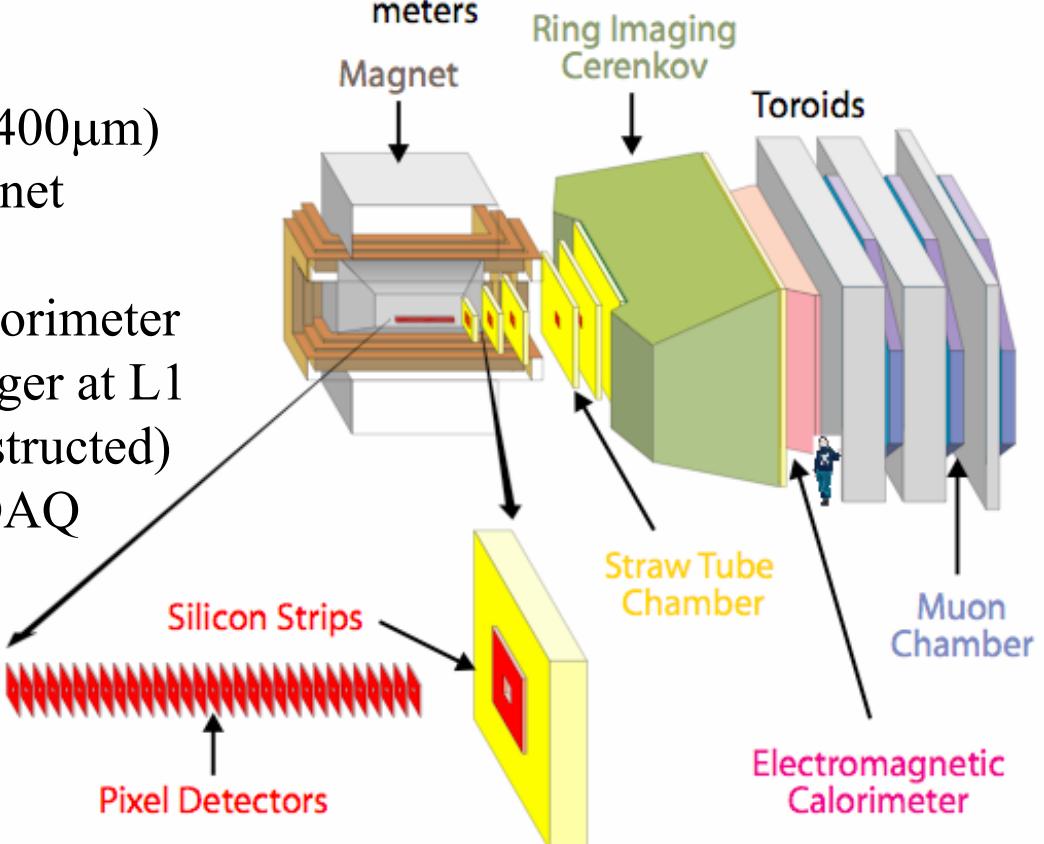


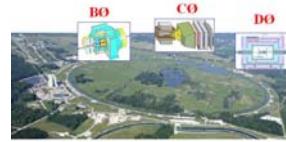
# The BTeV Detector



## Main/Unique Features

- Vertex pixel ( $50\mu\text{m} \times 400\mu\text{m}$ ) detector in dipole magnet
- RICH for particle ID
- $\text{PbWO}_4$  crystal EM calorimeter
- Vertex separation Trigger at L1 (primary vertex reconstructed)
- Powerful high speed DAQ (output up to 4KHz)

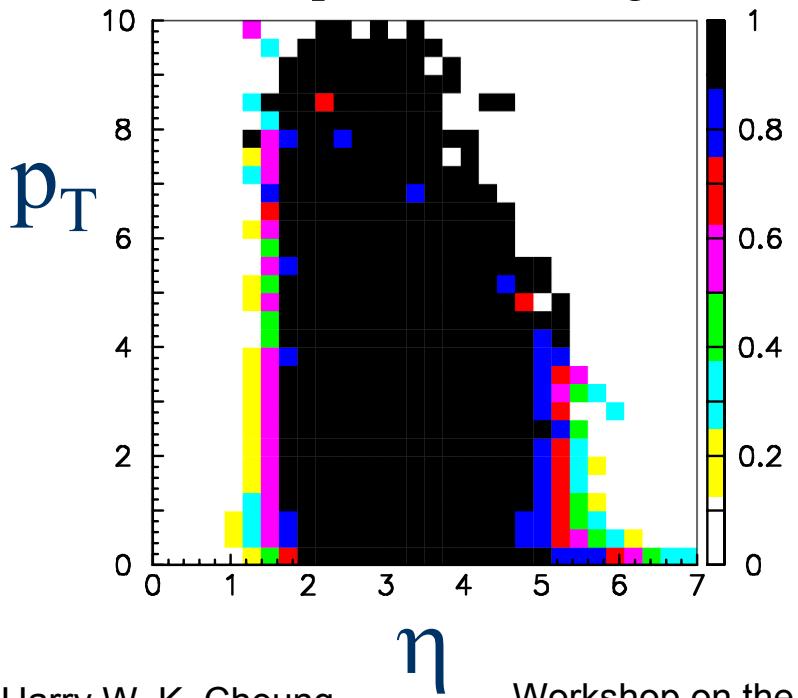




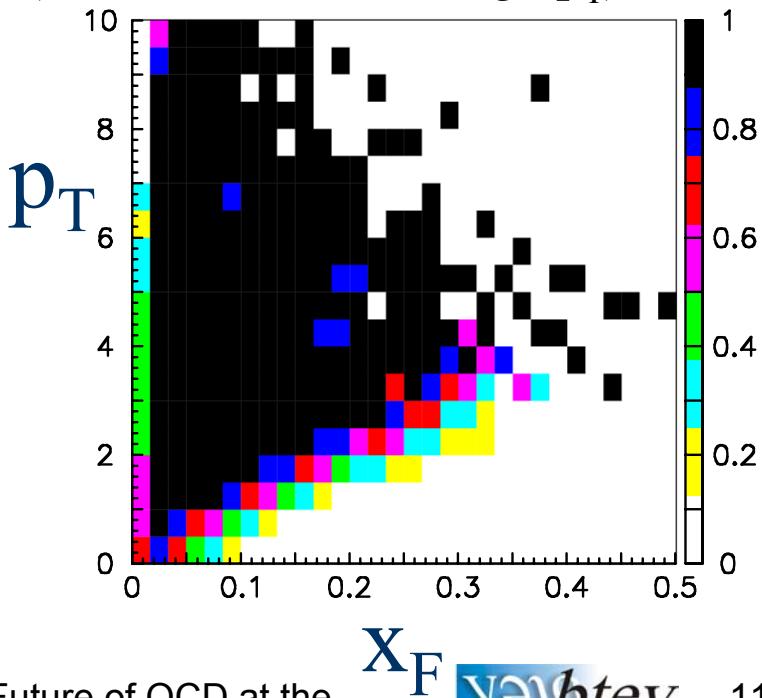
# Implications for QCD Physics

- Important BTeV detector features:
  - Excellent tracking 10 - 300 mrad ( $\eta \sim 1.9 - 5.3$ ) for single tracks
    - ◊ Good (flat) acceptance down to small angles and small  $p_T$

Acceptances for single tracks (lack of statistics at high  $p_T$ ):



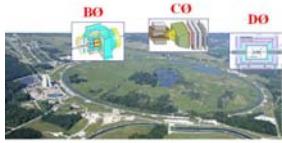
Harry W. K. Cheung



Workshop on the Future of QCD at the  
Tevatron, May 22, 2004

vbftev

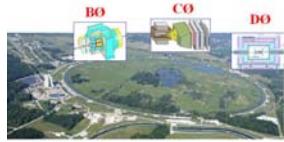
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# Implications for QCD Physics

- Important BTeV detector features:

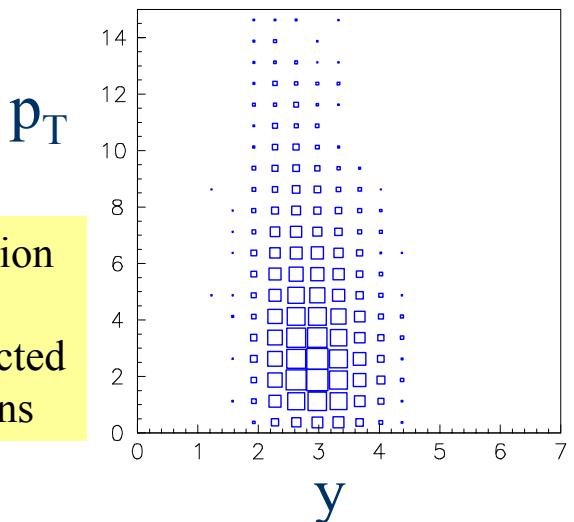
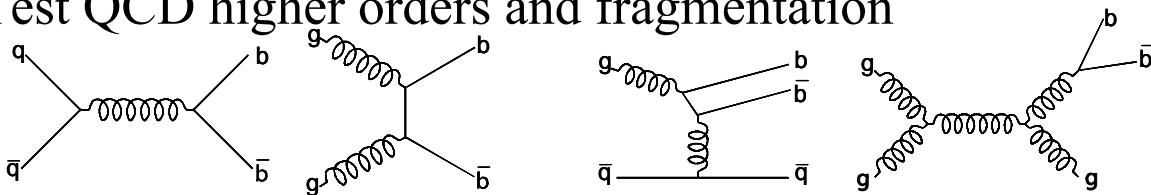
- Excellent tracking 10 - 300 mrad ( $\eta \sim 1.9 - 5.3$ )
  - ◊ Good acceptance down to small angles
  - ◊ Good acceptance for low  $p_T$  tracks
- EM PbWO<sub>4</sub> crystal calorimeter ( $25\lambda_0$  and  $1\lambda_I$ )
  - ◊ Excellent (multiple) photon detection and resolution
- No Hadronic calorimeter, no  $4\pi$  coverage
  - ◊ No jet studies? (jets with poor energy resolution)
  - ◊ No missing  $E_T$  measurement, No rapidity-gap detection
- Trigger on displaced tracks/vertices or muons only
  - ◊ Excellent heavy quark production and decay studies
  - ◊ No trigger for e.g. direct photon studies, diffractive, jets



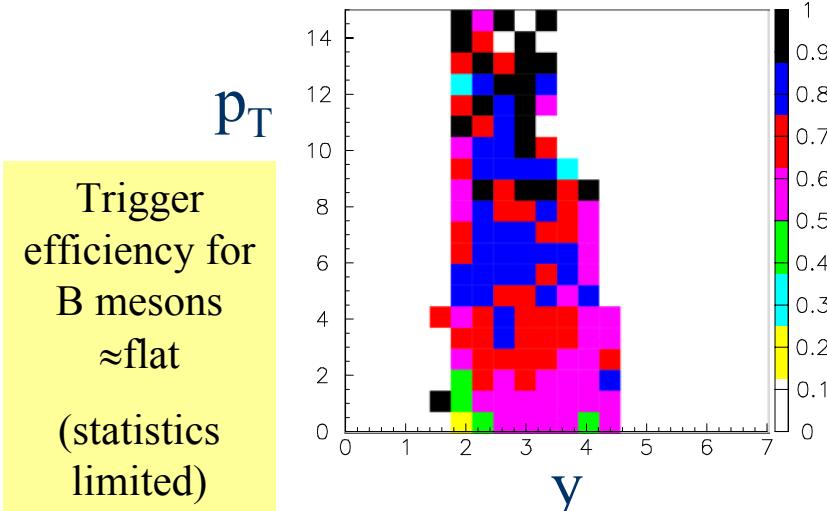
# QCD Physics at BTeV

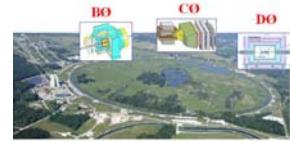
Heavy quark production in the forward region:

- Study region of  $(p_T, y)$  complementary to CDF, D0 central detectors
- Test QCD higher orders and fragmentation



Trigger efficiency for B mesons ≈ flat  
(statistics limited)



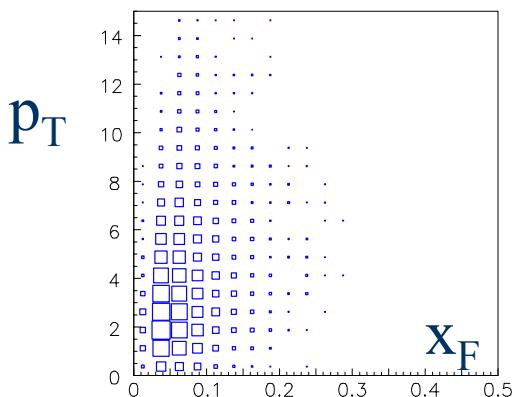


# QCD Physics at BTeV

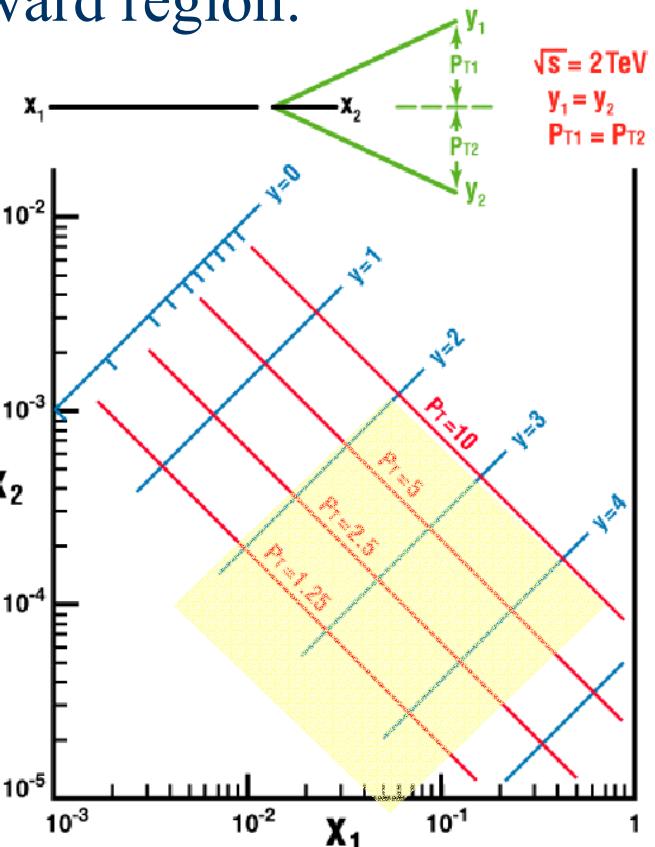
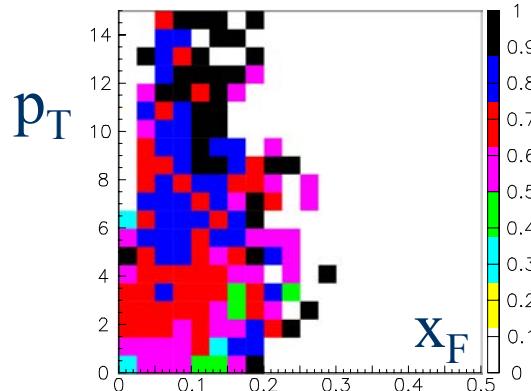
Heavy quark production in the forward region:

- Probe PDF's at low and high  $x_{Bj}$

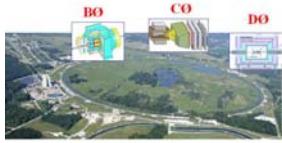
Distribution  
of  
reconstructed  
B mesons



Trigger  
efficiency for  
B mesons  
 $\approx$ flat  
(statistics  
limited)



From M.Albrow, "GTEV", DESY, Mar. 2004



# QCD Physics at BTeV

Heavy quark production -  $b\bar{b}$  correlations ( $\Delta\phi, \Delta y, \Delta p_T, \dots$ )

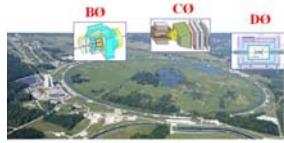
- Sensitive to higher order QCD contributions & low x in PDF(?)
- Less model dependence in QCD predictions(?)

Our studies concentrated on rare decays and tagging, but...

- Estimate  $\sim 10^7$  fully reconstructed B mesons (in 2  $\text{fb}^{-1}$ )
- $\sim 10^6$  fully recon. B + opposite tagged  $\overline{B}$  (not a jet)
- $\sim 10^3$  fully recon. BB + B $\overline{B}$  (c.f.  $10^5$ - $10^6$  di-b-jets CDF/D0)
- $\sim 10^4$ - $10^5$  fully reconstructed D $\overline{D}$  (depends on trigger)

Could also look at bb or  $\bar{b}\bar{b}$  events (besides from B mixing)

- E.g. due to gluon splitting in fragmentation
- SUSY  $\tilde{g} \rightarrow b\tilde{b}$  (~c.f. done at Run I and Run II?)



# QCD Physics at BTeV

Drell-Yan processes as probes of PDF (not direct photon)

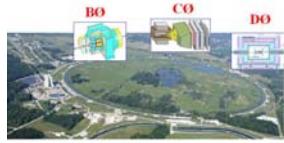
- Possible to trigger, but backgrounds unknown at low dilepton mass

Production of  $J/\psi$  and  $\Upsilon$  in the forward region

- Useful in discriminating NRQCD vs CEM, colour-singlet vs octet?
- Can reconstruct excited states of  $c\bar{c}$  and  $b\bar{b}$  (different  $J^P$ ) using  $\gamma$ 's

Heavy quark spectroscopy (excellent  $\gamma$  det. and particle ID)

- $B_c$  spectroscopy and decays,  $\sim 10^4$  fully reconstructed ( $\sim 10^3$  Run II)
- Spectroscopy of other  $b$  and  $c$  hadrons (many excited states)
- Light quark spectroscopy via  $B$  and  $D$  meson decays



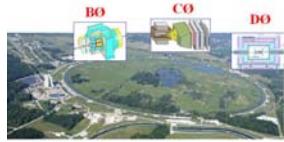
# QCD Physics at BTeV

Search/measure more exotic quark states

- Must be able to trigger on these states (lifetime or muons in decay)
- $qqQ$  and  $qQQ$  and even  $QQQ$  baryons
- pentaquarks, tetraquarks and hybrids with  $b$  and  $c$  quarks

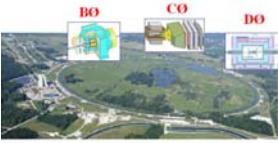
More QCD Physics at BTeV?

- Besides concerns of uncertainties in extracting CP-violating/CKM measurements in  $B$  decays, not much focus on possible QCD physics
- Not trying to sell QCD physics at BTeV, but this is an excellent opportunity to see what could be measured at BTeV and get collaborators who might want to do this type of physics



# Summary

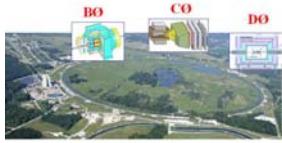
- BTeV is an experiment to study CP violation, rare and forbidden b & c decays in the forward region
- Goal for BTeV is to discover New Physics, or help interpret New Physics found elsewhere, using b & c decays; &
- Measure Standard Model “fundamental constants”
- Although QCD physics has not been a focus for BTeV there will be many interesting areas of study due to detection in the forward region, excellent photon detection & particle ID, and excellent efficiency for b & c hadron reconstruction
- This is an excellent opportunity to see if BTeV can do the type of QCD physics you are interested in.



# Proceed to Backup Slides

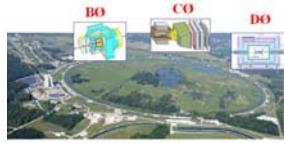
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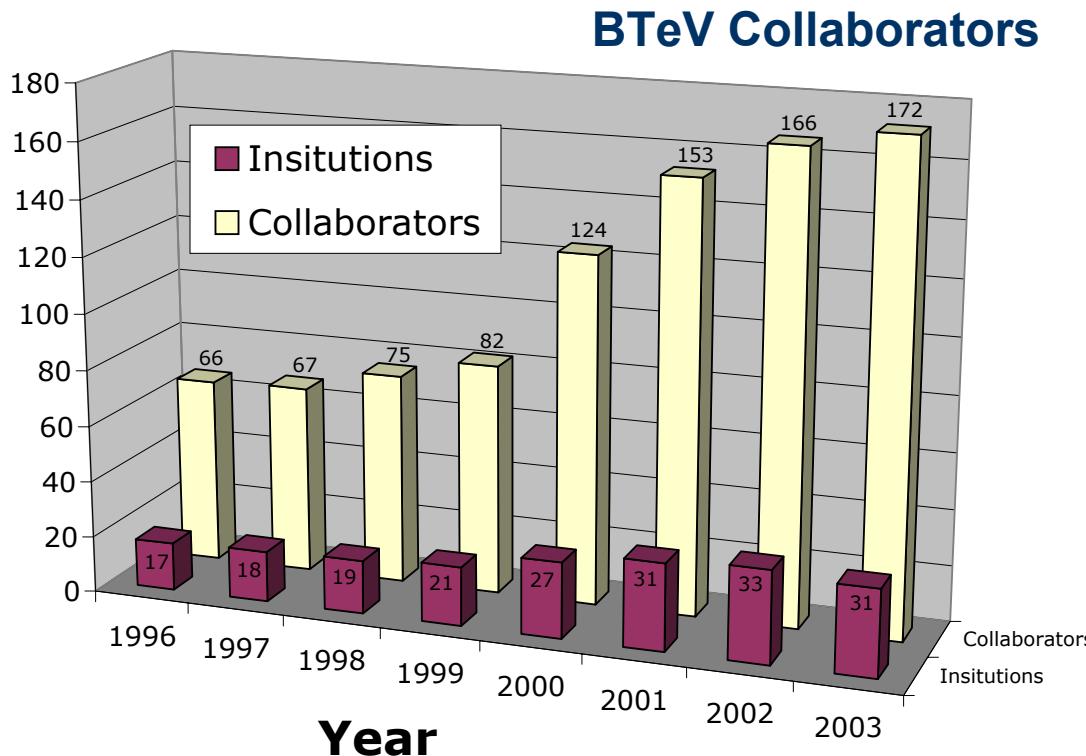
# Brief History and Status of BTeV

- May 1997 - EOI, 161 pages
- Dec. 1997 - Addendum, 62 pages - address PAC concerns  
⇒ BTeV becomes a R&D project
- May 1999 - Preliminary TDR, 373 pages (full BTeV)
- May 2000 - Proposal, 429 pages, submitted to Fermilab  
June 2000 ⇒ PAC unanimously recommends Stage 1 approval  
⇒ Approval from Director (2-arm)
- Mar. 2002 - Proposal update, 126 pages (request from Lab, 1-arm)  
⇒ PAC unanimously recommends approval of descoped BTeV  
⇒ Approval from Director (1-arm)
- Oct. 2002 - Fermilab conducts cost review of BTeV (Temple)
- Mar. 2003 - Review of BTeV by P5  
⇒ Oct. 2003 - P5 supports building BTeV and recommends earliest construction  
⇒ Nov. 2003 – BTeV makes the Near-term Priorities list of the DOE “Facilities for the Future of Science – A 20 Year Outlook” announced by Spencer Abraham  
⇒ Feb. 2004 – BTeV received DOE CD-0 (Mission need for BTeV)
- Mar. 2004 - Temple review of BTeV cost range and schedule range



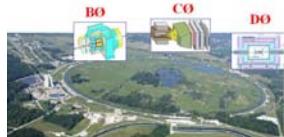
# Continual and Growing interest in BTeV

- Despite long review and approval process and problems for universities getting funding (e.g. for R&D):



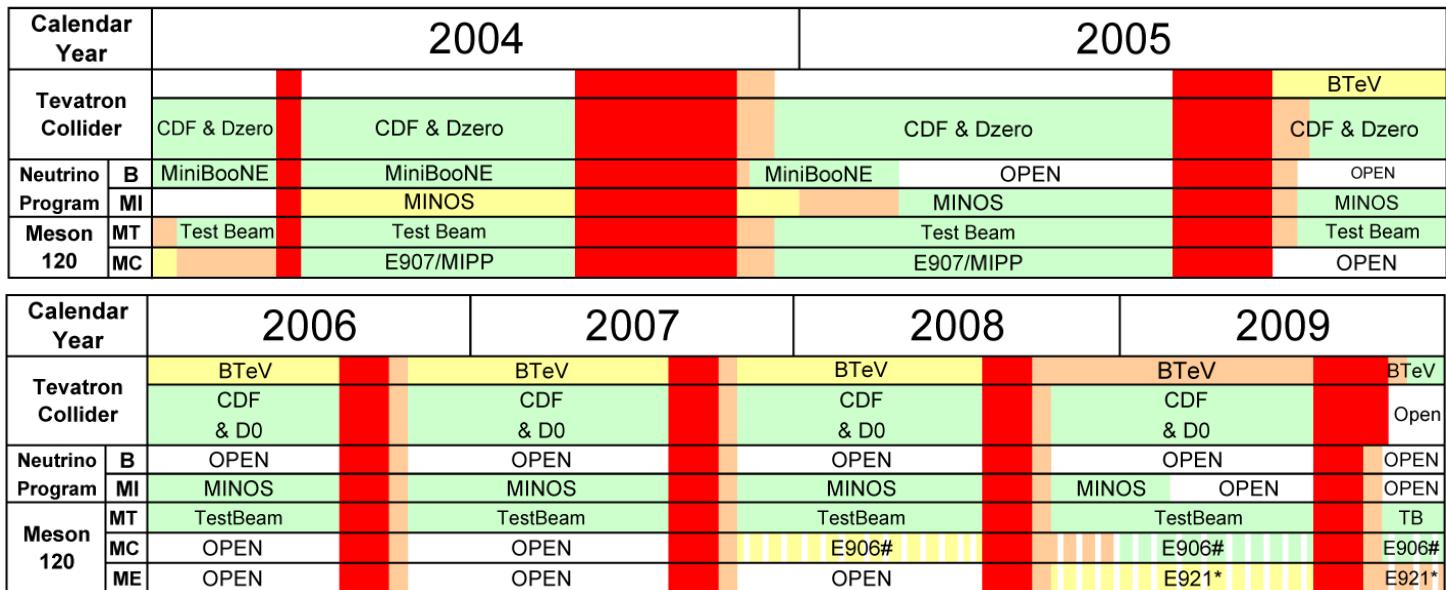
Most of these  
are senior  
members -  
expect to  
grow to 300.

- There is very strong interest in the physics and technology of BTeV



# Schedule

- If we get DOE approval and funding:



We are very excited about BTeV and eager to get construction funded and started!

We welcome new collaborators!